

AN STM STUDY OF CLEAN AND Cs-COVERED InSb(110)*

L. J. Whitman,[†] Joseph A. Stroscio, R. A. Dragoset, and R. J. Celotta
 National Institute of Standards and Technology, Gaithersburg, Maryland 20899

Although many scanning tunneling microscopy (STM) studies of semiconductors have been reported, most have been of elemental Si surfaces. To date, very few STM studies of clean *compound* semiconductor surfaces reporting *atomic-resolution* have been published [to our knowledge only GaAs(110) and GaAs(100)]. This may be due to the relative difficulty of obtaining atomic resolution images of these surfaces compared to elemental Si surfaces; lower tunnel currents must be employed and the surface charge density corrugations tend to be smaller. Application of the STM to the study of III-V compound semiconductors, however, is particularly interesting on the (110) surfaces due to the polar nature of these materials. The occupied surface state density tends to be concentrated on the group-V anion, with the unoccupied state density on the group-III cation. This enables atom-selective imaging of the different chemical elements on these surfaces.¹

We have employed STM to obtain atomic-resolution images of clean and Cs-covered InSb(110) surfaces. By simultaneously imaging the clean InSb(110) surface at both positive and negative sample bias the empty and filled state densities concentrated on the In and Sb atoms, respectively, have been selectively imaged. The In state density is shifted with respect to the Sb approximately one-half a unit cell along the $[1\bar{1}0]$ direction as expected. Along the $[001]$ direction the In state density is displaced slightly more than one-third a unit cell, 2.4 ± 0.4 Å, a distance determined by the surface buckling.¹ The measured displacement is in good agreement with that expected for the calculated buckling angle of 30° .² A variety of surface defects have also been observed, including those that appear to be simple anion vacancies and more complicated Schottky defects. In addition, the narrow band gap of InSb (~ 0.1 eV) has been observed in measurements of the tunnel current vs voltage.

Cs adsorbed on room temperature InSb(110) forms long (> 300 Å) zig-zag chains along the $[1\bar{1}0]$ direction, similar to those observed on GaAs(110).³ The zig-zag chain structure is preferred despite the large Cs-Cs nearest-neighbor distance of 8.0 Å on this surface [as compared to 6.9 Å on GaAs(110) and 5.2 Å in bulk Cs]. Tunnel current vs voltage measurements reveal that the Cs chains are *nonmetallic*. Surprisingly, the apparent band gap is found to be *larger* (~ 0.3 eV) over the chains than over the bare surface (~ 0.1 eV). This is in contrast to our observations of zig-zag Cs chains on GaAs(110), where we find the apparent band gap to be *smaller* (~ 1.0 eV) over the chains than over the bare surface (~ 1.4 eV). Possible explanations for these observations will be discussed.

[†] NRC/NIST Postdoctoral Research Associate

* Supported in part by the Office of Naval Research.

¹ R.M. Feenstra, Joseph A. Stroscio, J. Tersoff, and A.P. Fein, Phys. Rev. Lett. 58, 1192 (1987).

² C. Mailhot, C.B. Duke, and D.J. Chadi, Surf. Sci. 149, 366 (1985).

³ P.N. First, R.A. Dragoset, Joseph A. Stroscio, R.J. Celotta, and R.M. Feenstra, J. Vac. Sci. Technol. 7, 2868 (1989).